Assessment of the Regeneration Potential of Red Oaks and Ash on Minor Bottoms of Mississippi

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ABSTRACT: *Plots were established to monitor the success of advance regeneration for red oaks and ash on eight high quality sites on minor bottoms in Mississippi. Data were collected pre- and post-harvest, and annually for 3 yr following harvest. Red oak and ash stems were initially categorized by height class, or by diameter class for those stems at least 1 in. in diameter at breast height. Survival and competitive position were monitored to provide estimates of the probability of producing at least one free-to-grow stem 3 growing seasons following stand harvest. Regardless of species, the competitive advantage of larger seedlings and stump sprouts over smaller seedlings (less than 1 ft tall) was clear. Less than 10% of the smaller seedlings were free-to-grow after 3 growing seasons, whereas 26% to 71% of the larger seedlings and stump sprouts were judged free-to-grow after the same amount of time. Results were used to revise an existing regeneration assessment system. A field tally sheet was developed to aid in the application of the revised system. South. J. Appl. For. 23(3): 133–138.*

One of the challenges in hardwood silviculture is to successfully regenerate stands following harvest. High value species such as red oaks (*Quercus* spp.) and ash (*Fraxinus* spp.) commonly occupy a smaller percentage of the newly regenerated stand than they did in the parent stand (Beck and Hooper 1986, Loftis 1988), especially on productive sites. A lack of regeneration success for red oak has been documented in both operational and experimental settings (Beck and Hooper 1986, Loftis 1988, Johnson 1979, Kennedy 1989). Much of the blame for regeneration failure can be placed on a high mortality rate for advance oak regeneration due to competition from understory species (Lorimer 1993). Slow juvenile growth, poor response to release, and a general inability to respond to rapid changes in their environment put oak seedlings at a disadvantage relative to more shade tolerant species in undisturbed sites, or with faster growing species on open, or disturbed, sites (Hodges and Gardiner 1993).

A key consideration in the oak regeneration process is the assessment of the adequacy of advance regeneration. Various combinations of advance reproduction and stump sprout potential are used or have been suggested for different regions to meet different stocking objectives. Oliver (1978), working with red oaks in the northeastern United States, felt that as few as 60 well-distributed stems of advance reproduction or stump sprouts would be sufficient to provide 45 dominant trees at rotation age. In the North Central region, Sander et al. (1976) recommended 433 well-distributed stems/ac of advance reproduction at least 54 in. tall to ensure an adequately stocked oak stand. In the Lake States, a minimum of 400 seedlings or sprouts/ac greater than 1 ft in height was used by the USDA Forest Service (Arend and Scholtz 1969).

The influence of site quality must also be considered when assessing the adequacy of advance regeneration. Stands with low or medium site quality have typically been easier to regenerate than those with high site quality, mainly due to the greater presence of competition on high quality sites (Johnson 1979, Clark 1970). Guidelines, or evaluation systems, for medium and low quality sites include those developed by Dey (1991), Grisez and Peace (1973), Marquis and Bjorkbom (1982), Sander et al. (1976) and Waldrop et al. (1986). Guidelines designed for high quality sites are less common and include efforts by Loftis (1990), for red oaks in the southern Appalachians and Johnson (1980), for a variety of southern bottomland hardwoods.

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Johnson cautioned that his system was preliminary and required validation before broad application of its use. An initial exploration of the usefulness of the Johnson system was reported by Johnson and Deen (1993). The authors suggested that a further refinement of the system's threshold value for adequate stocking, especially in relation to seedling size class, may be necessary. Johnson and Deen (1993) recommended caution in concluding regeneration success for any given plot if the points needed to surpass their threshold were generated mostly from small seedlings. Conversely, the authors implied that some plots that scored just below the threshold, but contained mainly larger seedlings, may indicate successful regeneration.

The objectives of this study were to evaluate Johnson's system as it related to red oaks and ash on high quality bottomland sites, and to suggest revisions for this system where necessary. Two advantages of Johnson's method are its simplicity and ease of use for field foresters. Any recommendations for a new system would strive to maintain these properties.

Methods

Eight stands located on minor bottoms in three counties of Mississippi (Noxubee, Oktibbeha, and Wayne) were chosen for the study. Although four different soil types were present in the eight stands, the soils shared the characteristics of being somewhat poorly drained, with moderate to slow permeability, and medium to very high available water capacity. Slopes were from 0 to 5%, surface soil acidity ranged from a pH of 5.3 to 4.5, and texture ranged from silty loam to silty clay loam to silty clay. The sites experienced annual flooding for brief periods of time during the winter and early spring. Red oak site indices (base age 50) were approximately 94 to 97 ft (USDA 1973, 1986). The red oaks included in the study were cherrybark (*Quercus pagoda* Raf.), water (*Quercus nigra* L.), willow (*Quercus phellos* L.), and Shumard (*Quercus shumardii* Buckl.). The only ash species included in the study was green ash (*Fraxinus pennsylvanica* Marsh.).

Prior to harvest, the overstory composition of each stand was noted in terms of percent basal area by species. Sweetgum (*Liquidambar styraciflua* L.) was the most common single species, accounting for an average of 22% of the basal area. The red oaks mentioned above comprised an average of 25%, while ash basal area was only 2%. The low occurrence of ash in the overstory of the pre-harvest stands led to smaller than desirable sample sizes in the regeneration tallies. A total of 36 different species occurred in the overstory of the eight stands. A complete listing by basal area can be found in Hart (1994).

Circular plots (1/100th ac) were established in all stands prior to harvest. The number of plots varied by stand size, but a minimum of 10 plots were installed per stand for a total of 114 plots. Within each plot, data were collected both pre- and post-harvest, and annually for 3 yr following harvest. For red oak and ash seedlings, pre-harvest height class (< 1 ft, 1–3 ft, and > 3 ft) was recorded as well as the diameter at breast height (dbh) of trees that would potentially provide stump sprouts. These size classes were chosen to coincide with those used in Johnson's system.

All eight stands were harvested in mid-summer through fall with chain saws and rubber-tire skidders. Skidded log length was limited to a maximum of 32 ft. For six of the stands, all merchantable timber was removed, while seed trees were left on the remaining two. During, or soon after, the harvesting operation, all noncommercial residual trees 1.5 in. in dbh or greater were felled. Annual remeasurements of the plots were conducted following the growing season (between August 1 and November 1). Height, root collar diameter, and competitive position were recorded for all red oak and ash reproduction.

Competitive position was defined as overtopped (OT), medium competition (MC), or free-to-grow (FTG). An OT position was assigned to those seedlings which had direct overhead competition. An MC position was assigned to those seedlings which had not achieved the height of surrounding competition, but which still received direct sunlight to their terminal leader. An FTG position was assigned to those seedlings which were nearly as tall or taller than the immediate competition and received direct sunlight from above, or those seedlings which had no immediate woody competition. Also noted was the presence of new sprouts (seedling or stump) for these species.

The percentage of pre-harvest individuals for all red oak and ash regeneration size classes that produced a free-to-grow stem after 3 growing seasons was calculated. From these percentages, the probability of producing at least one free-to-grow individual was determined for each size class. A more detailed description of the study methods can be found in either Hart (1994) or Hart et al. (1995).

Results

The competitive status of seedlings and stump sprouts at the end of the third growing season following harvest was summarized (Tables 1 and 2). Size classes for stumps originating from trees more than 5 in. dbh are not presented in Table 1 or 2 since too few observations were recorded to allow meaningful percentages to be calculated. Also, the small sample sizes for the ash regeneration results that are presented (Table 2) suggest caution in drawing conclusions from these data. Regardless of species, however, the competitive advantage that larger seedlings and stump sprouts had over smaller (< 1 ft tall) advance regeneration in this study was clear. Less than 10% of the smaller seedlings were free-to-grow after 3 growing seasons, whereas 26% to 71% of the larger seedlings and stump sprouts were judged free-to-grow after the same amount of time. Unfortunately, few studies in the southern United States, as compared to the north-central states, have been completed, verifying the role of stump sprouting for trees of any given dbh. Reliance on stump sprouts, even those from small diameter trees, may involve significant risk.

Application of Stocking Probability

Earlier research in central Mississippi bottomland hardwood stands suggested that approximately 75 to 100 free-to-grow oak stems/ac were sufficient to assure full stocking (Clatterbuck and Hodges 1988). Thus, if a "stocked"

Table 1. Percent of the red oak stems existing prior to stand harvest that survived 3 yr after overstory removal, reported by competitive position and size class. Results are from plots located on minor bottoms of Mississippi.

Initial size class	n	Mortality	Competitive position* OT	MC	FTG
		(%)			
Seedlings					
< 1 ft	239	70.7 (2.9)†	12.5 (2.1)	8.4 (1.8)	8.4 (1.8)
1–3 ft	159	44.6 (3.9)	14.5 (2.8)	14.5 (2.8)	26.4 (3.5)
> 3 ft	122	49.2 (4.5)	4.9 (1.9)	7.4 (2.4)	38.5 (4.4)
Stumps††					
1–5 in.	37	70.3 (7.5)	0.0 (0.0)	0.0 (0.0)	29.7 (7.5)

* The three possible competitive positions were: OT = overtopped, MC = medium competition, and FTG = free-to-grow.
† Numbers in parentheses indicate the standard errors of the reported percentages.
†† Dbh of tree that resulted in stump, in 1 in. classes (i.e., 1–5 in. size class contains pre-harvest trees with dbh's from 1.6 to 5.5 in.).

plot (1/100 ac in size) is defined as having at least one stem that is free-to-grow at the end of the third post-harvest growing season, and the FTG percentages from Tables 1 and 2 are treated as probabilities, then the probability of stocking may be calculated for each size class, independently, using

$$PFTG = 1 - \prod_{i=1}^{r} [1 - P(F \mid c_i)]^{n_i}$$

where

$PFTG$ = probability a plot will produce at least one free-to-grow stem after 3 growing seasons

c_i = stem size class c_i (i.e., < 1 ft, 1–3 ft, and > 3 ft tall)

n_i = number of seedlings in size class c_i

$P(F \mid c_i)$ = probability that a seedling will be free-to-grow given that it is in class c_i

r = number of classes with at least one individual present

For example, if a particular regeneration inventory plot has the following advance red oak reproduction,

2 seedlings < 1 ft

2 seedlings 1–3 ft

1 seedling > 3 ft

1 tree 1–5 in. dbh

the results in Table 1 (see FTG column) and the $PFTG$ equation would be applied as follows:

$$PFTG = 1 - [(1 - 0.084)^2 (1 - 0.264)^2 (1 - 0.385)^1$$

$$(1 - 0.297)^1] = 0.803$$

Thus, the plot has about an 80% chance of producing at least one FTG red oak. Similarly, a survey of advance ash regeneration would use the FTG percentages in Table 2 and the $PFTG$ equation to calculate the chance of producing at least one FTG ash. Of course, the information in both Tables 1 and 2 could be used together to calculate the overall probability that a plot would produce at least one desirable stem (either red oak or ash). For example, if a regeneration inventory plot had the following advance red oak and ash reproduction,

9 red oak seedlings < 1 ft

3 ash seedlings < 1 ft

Table 2. Percent of the ash stems existing prior to stand harvest that survived 3 yr after overstory removal, reported by competitive position and size class. Results are from plots located on minor bottoms of Mississippi.

Initial size class	n	Mortality	Competitive position* OT	MC	FTG
		(%)			
Seedlings					
< 1 ft	11	72.7 (13.4)†	18.2 (11.6)	0.0 (0.0)	9.1 (8.7)
1–3 ft	24	20.7 (8.3)	4.2 (4.1)	8.4 (5.7)	66.7 (9.6)
> 3 ft	44	18.2 (5.8)	0.0 (0.0)	15.9 (5.5)	65.9 (7.1)
Stumps††					
1–5 in.	14	14.3 (9.4)	0.0 (0.0)	14.3 (9.4)	71.4 (12.1)

* The three possible competitive positions were: OT = overtopped, MC = medium competition, and FTG = free-to-grow.
† Numbers in parentheses indicate the standard errors of the reported percentages.
†† Dbh of tree that resulted in stump, in 1 in. classes (i.e., 1–5 in. size class contains pre-harvest trees with dbh's from 1.6 to 5.5 in.).

1 ash seedling > 3 ft

1 red oak tree 1–5 in. dbh

the results in Table 1 and Table 2 (see FTG column) and the *PFTG* equation would be applied as follows:

$$PFTG = 1 - [(1 - 0.084)^9 (1 - 0.091)^3 (1 - 0.659)^1$$

$$(1 - 0.297)^1] = 0.918$$

Thus, the plot has about a 92% chance of producing at least one desirable FTG stem (either red oak or ash).

The *PFTG* equation is relatively easy to use in the office and lends itself well to a spreadsheet environment, but it may be cumbersome to apply in the field. One of the advantages of the system designed by Johnson was its ease of use. The assignment of points to each stem on the plot, using a tally sheet format, was easy to understand and apply by field foresters. The points for each stem on the plot were added, and if the total exceeded 12, then the plot was considered stocked. The disadvantage of the system was that it did not provide an estimate of the probability of stocking, but simply an indication of whether the plot should be considered stocked (12 or more points), or not stocked (less than 12 points).

Evaluation of Johnson's System

The probabilities calculated from Tables 1 and 2 can be used to evaluate the reproduction inventory system developed by Johnson (1980). Any plot receiving 12 or more points in Johnson's system was considered a stocked plot. The points assigned to the different size classes were as follows, regardless of species (red oak or ash):

seedlings < 1 ft—1 point each

seedlings 1–3 ft—2 points each

seedling > 3 ft—3 points each

trees 1–5 in. dbh—3 points each

Using the 12-point minimum for stocking, 12 seedlings less than 1 ft in height would result in a designation of "stocked" for any given plot. The actual probability that the plot would produce at least one FTG stem, using Table 1 and the *PFTG* equation would be 0.65, or a 65% chance of the plot being stocked. Similarly, if 6 seedlings 1 – 3 ft in height were recorded for a plot, again the plot would be considered "stocked"; however, the actual probability of producing at least one FTG stem would be 0.84, or an 84% chance of the plot being stocked. The same calculations have been conducted for the rest of the size classes for red oak stems, and for all ash stem size classes. The results are summarized in Table 3.

It is apparent from Table 3 that for any given plot considered "stocked" under Johnson's system, the chance of producing at least one FTG stem, depending on species and size class, may range from a low of 65% to a high of 99%. If one were to assume that about an 80% chance of producing at least one FTG stem was an acceptable indicator of a stocked plot, then the point value assigned for small seedlings seems to be too high. More than 12 seedlings in this class would be required to provide a reasonable stocking probability. Conversely, the point value assigned for larger ash seedlings (1.0 to 3.0 ft, and > 3.0 ft) and stumps (1 to 5 in. dbh) would appear to be too low.

Table 3. Stocking probabilities associated with the point system developed by Johnson (1980) to assess potential regeneration success for southern bottomland hardwood stands. Probabilities were calculated independently for each size class using the percentage of seedlings initially found in pre-harvest plots that survived and were free-to-grow 3 yr after stand harvest.

Initial size class	Min no. stems for stocked plot*		Probability of producing at least one FTG stem	
	Red oak	Ash	Red oak	Ash
Height				
< 1 ft	12.0	12.0	0.65	0.68
1–3 ft	6.0	6.0	0.84	0.99
> 3 ft	4.0	4.0	0.86	0.99
Dbh† (1 in. classes)				
1–5 in.	4.0	4.0	0.76	0.99

* Recommended by Johnson's (1980) system.
† Dbh of tree that resulted in stump, in 1-in. classes (i.e., 1–5 in. size class contains pre-harvest trees with dbh's from 1.6 to 5.5 in.).

Point System Revision

If the point system were revised to reflect the quantitative information available from the current study, then the discrepancies in stocking probability would be eliminated. In other words, the same total points generated from stems in any size class, or species would result in the same probability of stocking. However, it is likely that an acceptable threshold for stocking probability would differ by situation, and by the experience of individual managers. Rather than setting a static threshold, it may be that providing the expected probability of stocking for each plot would be more useful to decision-makers.

A revised point system may be developed from the FTG percentages in Tables 1 and 2, using the smallest FTG percentage as a common denominator. The red oak seedlings in the "less than 1 ft" height class have the lowest FTG percentage, 0.084 (Table 1). It would take relatively more of these seedlings on a plot to assure the same probability of stocking than if a seedling in another height class (or another species) was present. Therefore, if red oak seedlings in the smallest height class were given a total of 1 point each, other seedlings should be assigned relatively more points for each stem present on a plot. The number of points to assign to each height class, by species, can be determined by solving the following equation

$$1 - (1 - 0.084)^1 = 1 - [1 - P(F \mid c_i)]^{1/p_i}$$

for p_i, where p_i is defined as the relative number of points to be allotted to size class c_i.

For example, the number of points to be assigned to stems in the red oak height class of "1.0 to 3.0 ft" would be calculated as

$$1 - (1 - 0.084)^1 = 1 - [1 - 0.264]^{1/p_i}$$

and solving for p_i would yield

$$p_i = 3.49$$

Every red oak stem counted in this class would receive approximately 3.5 points. The same process may be repeated for each size class and species, leading to the results summarized in Table 4. The points per count have all been rounded to the nearest half-integer to facilitate the application of the revised point system in a tally sheet format.

Tally Sheet Revision

The information from Table 4 was used to produce a revision of Johnson's tally sheet (Figure 1) for the inventory of advance red oak and ash reproduction. The form is designed for use with 1/100-ac plots. Red oak and ash regeneration counts are maintained separately to allow for independent evaluation of regeneration potential by species. The total count for either species, or for combined species may be compared to the probabilities on the right side of the tally sheet. For example, if the following stem counts were noted for a plot,

6 red oak seedlings < 1 ft

2 ash seedlings > 3 ft

1 red oak tree 1 – 5 in. dbh

Each of the six red oak seedlings receives 1.0 point, while the 1 – 5 in. red oak tree receives 4.0 points for a total of 10 points. Ten points coincides with a 58% probability of the plot producing at least one FTG red oak stem (see the table on the right side of the tally sheet, Figure 1). The two ash seedlings each receive 12 points for a total of 24. This total indicates an 88% probability that the plot will produce at least one FTG ash stem. The red oak and ash points may also be combined to yield 34 total points, which would coincide with a 95% stocking probability for the plot.

In practice, a separate tally sheet should be completed for each plot, and the results averaged for the stand being evaluated. A high level of variation across plots, even when the overall average stocking probability is high, would indicate that there are some areas in the stand that may not show evidence of adequate advance regeneration. The spatial distribution of regeneration may be as important as the average stocking probability to the future stocking of the stand. It is recommended that the plots be established on a grid that will allow the results to be mapped onto the stand to help visualize the distribution of stocking probability. In this way, problem areas may be identified and further investigated.

Plot # ______
Date ______
Location ______

Size Class	Red Oaks		
Height	count	points per count	Total Points
< 1 ft		1.0	
1 to 3 ft		3.5	
> 3 ft		5.5	
Dbh (1-in. classes)			
1 to 5 in.		4.0	
Total red oaks points for this plot			

Size Class	Ash		
Height	count	points per count	Total Points
< 1 ft		1.0	
1 to 3 ft		12.5	
> 3 ft		12.0	
Dbh (1-in. classes)			
1 to 5 in.		14.0	
Total ash points for this plot			

Combined red oak and ash points for this plot	

Probability of red oak stocking ______

Probability of ash stocking ______

Probability of either red oak or ash stocking ______

Total Points	Probability
35	0.95
34	0.95
33	0.94
32	0.94
31	0.93
30	0.93
29	0.92
28	0.91
27	0.91
26	0.90
25	0.89
24	0.88
23	0.87
22	0.85
21	0.84
20	0.83
19	0.81
18	0.79
17	0.77
16	0.75
15	0.73
14	0.71
13	0.68
12	0.65
11	0.62
10	0.58
9	0.55
8	0.50
7	0.46
6	0.41
5	0.36
4	0.30
3	0.23
2	0.16
1	0.08

Figure 1. Field tally sheet for regeneration assessment. The tally sheet was based on the point system developed by Johnson (1980) and revised to reflect free-to-grow probabilities generated by the current study.

Conclusion

The concerns of Johnson and Deen (1993) regarding the reliance on small seedlings (< 1.0 ft), even on those plots that surpass the threshold of 12 points postulated by Johnson (1980), or possibly discounting the effectiveness of large seedlings that approach, but do not surpass the 12 point threshold, have been confirmed by this study. Although Johnson's system was well designed and very useful in its original form, the system gave too much weight to small seedlings, both for red oaks and ash, when determining the stocking of any given plot. Also, the use of a threshold value

Table 4. Summary of the revised points per count assigned to each regeneration size class and species. Revisions were made to the point system proposed by Johnson (1980) to reflect the free-to-grow probabilities found in the current study. All points presented were rounded to the nearest half-integer.

	Red oaks		Ash	
Initial size class	FTG (%)	Points per count	FTG (%)	Points per count
Height				
< 1 ft	0.084	1.0	0.091	1.0
1–3 ft	0.264	3.5	0.667	12.5
> 3 ft	0.385	5.5	0.659	12.0
Dbh* (1 in. classes)				
1–5 in.	0.297	4.0	0.714	14.0

[1] Dbh of tree that resulted in stump, in 1-in. classes (i.e., 1–5 in. size class contains pre-harvest trees with dbh's from 1.6 to 5.5 in.).

to designate stocked versus unstocked plots can be eliminated by simply estimating the probability of stocking directly. Decisions on the adequacy of advance regeneration can thus be left to the individual manager, based on his or her estimate of the minimum acceptable probability of stocking for any given stand.

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